[12pt,aaspp4]aastex

JONES, ET AL. THE JETS AND DISK IN NGC 4261

document The Radio Jets and Accretion Disk in NGC 4261

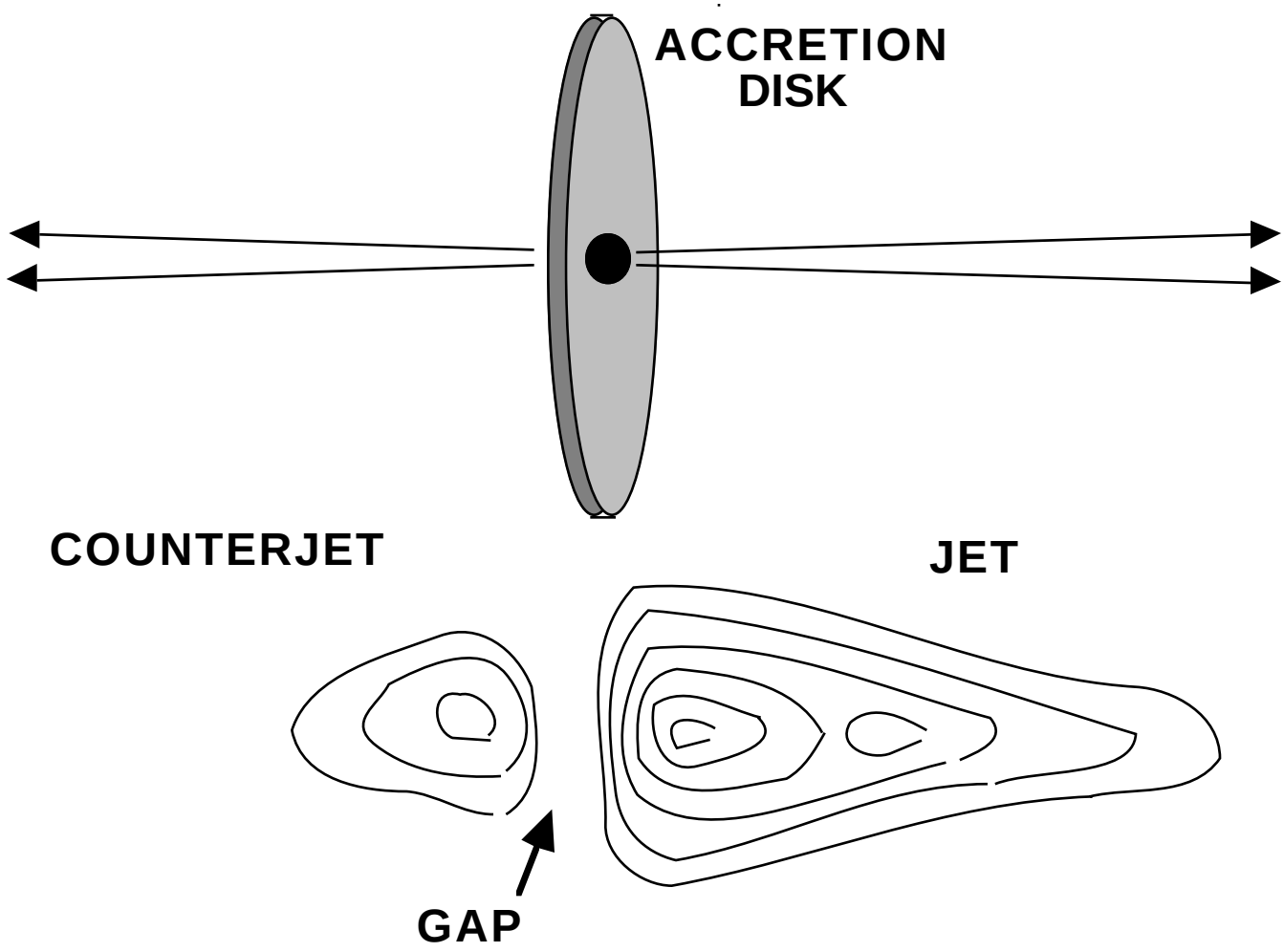
Dayton L. Jones Jet Propulsion Laboratory, California Institute of Technology, Mail Code 238-332, 4800 Oak Grove Drive, Pasadena, CA 91109 dj@bllac.jpl.nasa.gov

Ann E. Wehrle Jet Propulsion Laboratory, California Institute of Technology, Mail Code 301-486, 4800 Oak Grove Drive, Pasadena, CA 91109 aew@ipac.caltech.edu

David L. Meier Jet Propulsion Laboratory, California Institute of Technology, Mail Code 238-332, 4800 Oak Grove Drive, Pasadena, CA 91109 dlm@cena.jpl.nasa.gov

B. Glenn Piner Jet Propulsion Laboratory, California Institute of Technology, Mail Code 238-332, 4800 Oak Grove Drive, Pasadena, CA 91109 glenn@herca.jpl.nasa.gov

abstract The structure of AGN accretion disks on sub-parsec scales can be probed through free-free absorption of synchrotron emission from the base of symmetric radio jets. For objects in which both jet and counterjet are detectable with VLBI, the accretion disk will cover part of the counterjet and produce diminished brightness whose angular size and depth as a function of frequency can reveal the radial distribution of free electrons in the disk. The nearby (41 Mpc, independent of H_0) FR-I radio galaxy NGC 4261 contains a pair of symmetric kpc-scale jets. On parsec scales, radio emission from the nucleus is strong enough for detailed imaging with VLBI. We present new VLBA observations of NGC 4261 at 22 and 43 GHz, which we combine with previous observations at 1.6 and 8.4 GHz to map absorption caused by an inner accretion disk. The relative closeness of NGC 4261 combined with the high angular resolution provided by the VLBA at 43 GHz gives us a very high linear resolution, approximately 2×10^{-2} pc $\approx$ 4000 AU $\approx$ 400 Schwarzchild radii for a 5×10^8 $M_\odot$ black hole. The jets appear more symmetric at 1.6 GHz because of the low angular resolution available. The jets are also more symmetric at 22 and 43 GHz, presumably because the optical depth of free-free absorption is small at high frequencies. At 8.4 GHz neither confusion effect is dominant and absorption of counterjet emission by the presumed disk is detectable. We find that the orientation of the radio jet axis is the same on pc and kpc scales, indicating that the spin axis of the inner accretion disk and black hole has remained unchanged for at least 10^6 (and more likely $> 10^7$) years. This suggests that a single merger event may be responsible for the supply of gas in the nucleus of NGC 4261. The jet opening angle is between 0.3° and 20° during the first 0.2 pc of the jet, and must be $< 5°$ during the first 0.8 pc. Assuming that the accretion disk is geometrically and optically thin and composed of a uniform 10^4 K plasma, the average electron density in the inner 0.1 pc of the disk is $10^3 - 10^8$ cm^{-3}. The mass of ionized gas in the inner pc of the disk is $10^1 - 10^3$ $M_\odot$, sufficient to power the radio source for $\sim 10^4 - 10^6$ years. Equating thermal gas pressure and magnetic field strength gives a disk magnetic field of $\sim 10^{-4} - 10^{-2}$ gauss at 0.1 pc. We include an appendix containing expressions for a simple, optically thin, gas pressure dominated accretion disk model which may be applicable to other galaxies in addition to NGC 4261.


ACCRETION
DISK
COUNTERJET
JET
GAP